明 細 書

弾性波フィルタおよびそれを用いた通信機

技術分野

[0001] 本発明は、弾性波フィルタおよびそれを用いた通信機に関し、詳しくは、弾性波を利用した弾性表面波フィルタや弾性境界波フィルタなどの弾性波フィルタおよびそれを用いた通信機に関する。

背景技術

[0002] 数十MHz～数GHzを通過帯域周波数とするバンドパスフィルタの一例として、弾性表面波フィルタを挙げることができる。弾性表面波フィルタは、小型、軽量であるという特徴から、近年、携帯型通信機に使用されている。

[0003] 弾性表面波フィルタの中にもいくつかの種類が存在するが、圧電基板上の表面波伝搬方向に沿って二つの反射器を設置し、その二つの反射器に挟まれた区間の中に入力用のIDTと出力用のIDTを交互に配設する縦結合共振子型弾性表面波フィルタは、帯域内周波数における挿入損失が小さく、かつ、平衡信号－不平衡信号変換が容易にできるという特徴から、携帯型通信機のフロントエンドに多用されている。

[0004] 縦結合共振子型弾性表面波フィルタの動作原理は、以下の通りである。

[0005] 入力された電気信号を入力用IDTが表面波に変換することで、二つの反射器の間に表面波の定在波を発生させる。そして、発生した定在波のエネルギーを出力用のIDTが電気信号へと変換することで、出力信号が発生する。このとき、入力用IDTおよび出力用IDTの電気信号－表面波変換効率が周波数特性を持ち、また、反射器の表面波反射効率が周波数特性を持つことから、縦結合共振子型弾性表面波フィルタは特定の周波数帯域内の信号だけを伝送するバンドパス特性を持つ。

[0006] 通過帯域外の信号減衰量を大きくしたい場合には、一つの圧電基板の上に、縦結合共振子型弾性表面波フィルタ素子を2つ以上形成し、それらをカスケード接続した構成の弾性表面波フィルタを使用する。複数の縦結合共振子型弾性表面波フィルタ素子をカスケード接続することにより、通過帯域外の信号は、おのおのの縦結合共振子型弾性表面波フィルタ素子によって順次減衰を受けるので、帯域外減衰量が大き

くなる(例えば、特許文献1参照)。

[0007] 図1に、圧電基板100の上に、2つの縦結合共振子型弾性表面波フィルタ素子106，112を形成して、それらをカスケード接続して形成した弾性表面波フィルタ150を示す。

[0008] 縦結合共振子型弾性表面波フィルタ106は、反射器101，105の間に3つのIDT102，103，104が、弾性表面波の伝搬方向を揃えて一列に配置されている。同様に、縦結合共振子型弾性表面波フィルタ112は、反射器107，111の間に3つのIDT108，109，110が、弾性表面波の伝搬方向を揃えて一列に配置されている。反射器101，105，107，111は周期的なグレーティングである。IDT102～104，108～110は、相互に間挿する櫛型電極である。

[0009] IDT102とIDT108が配線113で接続されるとともに、IDT104とIDT110が配線114で接続されることで、縦結合共振子型弾性表面波フィルタ素子106，112がカスケード接続されている。

[0010] 配線115～122は、パッド123～130(128なし)とIDT102～104，108～110との間で導通をとるための配線である。パッド123～127は接地用のパッドであって、接地して用いる。一方、パッド129は入力用のパッドであって、このパッドに入力電圧を印加する。パッド130は出力用のパッドであって、このパッドに出力電圧が発生する。

[0011] 反射器101，105，107，111、およびIDT102～104，108～110、および配線113～122、およびパッド123～130(128なし)は、すべて圧電基板100の上に形成された金属薄膜のパターンであって、薄膜微細加工プロセス、例えば、真空成膜、フォトリソグラフィー、エッチング、リフトオフなどによって形成される。

[0012] 図2に、圧電基板200上に、2つの縦結合共振子型弾性表面波フィルタ素子206，212を形成して、それらをカスケード接続して形成した不平衡信号－平衡信号変換機能付弾性表面波フィルタ250を示す。弾性表面波フィルタ150と共通する部分が多いため、弾性表面波フィルタ150と異なる点を中心に、以下に説明する。

[0013] IDT209が2つに分割されたIDTとなっており、このIDT209が平衡信号を発生するようになっている。パッド223～227を接地して、パッド229に入力不平衡信号を入

力すると、パッド230とパッド231に出力平衡信号が発生する。

[0014] 弾性表面波フィルタ250では、IDT202とIDT204の極性が反転されており、また、IDT208とIDT210の極性も反転されている。よって、接続配線213と接続配線214は逆相信号を伝送することになる。この手法は、弾性表面波フィルタ250の出力平衡信号の平衡度を向上させる働きがある。この手法を用いず、IDT202とIDT204の極性を同じにして、IDT208とIDT210の極性を同じにすることで、接続配線213と接続配線214が同相信号を伝送するようにしても、弾性表面波フィルタ250は不平衡信号－平衡信号変換機能付弾性表面波フィルタとして十分に機能するが、この手法を用いた方が、出力平衡信号の平衡度が良くなる。

[0015] ここまで弾性表面波フィルタについて述べてきたが、これと類似したフィルタとして、弾性境界波フィルタがある。弾性境界波フィルタは、弾性表面波フィルタと同様に、圧電基板上に金属薄膜からなるIDT及び反射器を形成して構成するフィルタである。例えば、圧電単結晶基板の表面にAlなどからなるIDT、反射器で構成されるフィルタ電極を形成し、その上に圧電単結晶とは弾性定数もしくは密度の異なるSiO_2などの充分厚い薄膜を形成したものである。作用原理や構成は、弾性表面波フィルタとほぼ同じであるが、弾性境界波フィルタは、素子形成された圧電基板面の上に固体層が設けられており、圧電基板と固体層の境界を伝搬する弾性波（弾性境界波）とIDTを相互作用させて動作する。弾性表面波フィルタでは、基板表面を拘束しないように、空洞を有するパッケージを用いる必要があるが、弾性境界波フィルタでは、波が圧電単結晶基板と薄膜との境界面を伝搬するため、空洞を有するパッケージを必要としないという長所がある。

[0016] 圧電基板の表面を伝搬する弾性表面波を用いて動作するのが弾性表面波フィルタであり、圧電基板と固体層の境界を伝搬する弾性境界波を用いて動作するのが弾性境界波であるが、両者の動作原理は基本的に同じであり、用いられる設計手法も類似している。

[0017] 本明細書及び特許請求の範囲においては、弾性表面波フィルタや弾性境界波フィルタのように、弾性波（レイリー波、SH波、擬似弾性表面波、Love波、Sezawa波、Stonely波、境界波など）を利用したフィルタの総称として「弾性波フィルタ」という呼称

を用いる。また、縦結合共振子型弾性表面波フィルタと縦結合共振子型弾性境界波フィルタの総称として「縦結合共振子型弾性波フィルタ」という呼称を用いる。

特許文献1:特開2002－9587号公報

発明の開示

発明が解決しようとする課題

[0018] 弾性波フィルタをはじめとする高周波用バンドパスフィルタには、良好なインピーダンス整合が求められる。入出力端においてインピーダンス整合の悪いフィルタ、すなわち入出力端における信号反射の大きいフィルタは、反射によって信号を損失する分、挿入損失が悪く(大きく)なるからである。また、フィルタの入出力端で反射した信号が、フィルタに接続する他の電子部品に再入力することによって、回路が異常発信などの不具合を発生する危険性があるからである。

[0019] ちなみに、「良好なインピーダンス整合」、「小さな信号反射」、「小さなVSWR(Voltage Standing Wave Ratio)」は、全て同義である。インピーダンス整合が良好であれば、信号反射は小さくなり、VSWRは小さくなる。VSWRが小さいことは信号反射が小さいことを意味し、これはすなわちインピーダンス整合が良好であることを意味する。

[0020] 圧電基板の上に複数の縦結合共振子型弾性波フィルタ素子を形成し、これらをカスケード接続して構成した弾性波フィルタにおいては、縦結合共振子型弾性波フィルタ素子間のカスケード接続点におけるインピーダンス整合が、弾性波フィルタ全体のインピーダンス整合に影響をもつ。これは、縦結合共振子型弾性波フィルタ素子間のカスケード接続点のインピーダンス整合が悪く、ここで信号の反射が発生すると、反射した信号が結局、弾性波フィルタの反射波としてフィルタ外部へと放射されてしまうからである。

[0021] 縦結合共振子型弾性波フィルタ素子間のカスケード接続点においては、カスケード接続点からみた一方の縦結合共振子型弾性波フィルタ素子のインピーダンスと、カスケード接続点からみたもう一方の縦結合共振子型弾性波フィルタ素子のインピーダンスが、複素共役になっていることが理想である。両者が複素共役の関係にあれば、カスケード接続点でのインピーダンス整合は完全であることになり、この部分での信

号反射は全く発生しない。

[0022] しかし、現実には、カスケード接続線とアース電位のパターンの間に入る寄生容量のために、カスケード接続点から見た縦結合共振子型弾性波フィルタ素子のインピーダンスは、どちらも容量性(インピーダンス虚部が負)になりやすい傾向があり、理想的な複素共役の状態(一方のインピーダンス虚部が正で、もう一方のインピーダンス虚部が負)にはなりにくい。これが、縦結合共振子型弾性波フィルタ素子間のカスケード接続点における信号反射を増大させる原因になっている。そして、結果的に、縦結合共振子型弾性波フィルタ素子をカスケード接続して構成する弾性波フィルタのVSWRを悪化させている。この問題は、使用する圧電基板の比誘電率が大きいほど、カスケード接続線とアース電位のパターンの間に入る寄生容量が大きくなるため、顕著になる。また、フィルタの通過帯域周波数が高くなるほど、寄生容量に流入する電流が増えるため、この問題は顕著になる。

[0023] 本発明の目的は、圧電基板上に複数の縦結合共振子型弾性波フィルタ素子を形成し、これらをカスケード接続して構成した弾性波フィルタにおいて、縦結合共振子型弾性波フィルタ素子間のカスケード接続線に入る寄生容量の悪影響を軽減することで、カスケード接続点のインピーダンス整合を改善し、弾性波フィルタ入出力端のVSWRを改善することである。

課題を解決するための手段

[0024] 本発明は、上記目的を達成するため、以下のように構成した弾性波フィルタを提供する。

[0025] 弾性波フィルタは、圧電基板上に弾性波の伝搬方向に沿って形成された3つのIDTをそれぞれ含む2つの縦結合共振子型弾性波フィルタがカスケード接続されたタイプのものである。前記縦結合共振子型弾性波フィルタの少なくとも一方は、カスケード接続された前記IDTの電極指のピッチがカスケード接続された前記IDTのコンダクタンスピークの周波数が他の前記IDTのコンダクタンスピークの周波数より高くなるように、他の前記IDTの電極指のピッチよりも小さい。

[0026] 上記構成において、縦結合共振子型弾性波フィルタは、一般に、カスケード接続されたIDTの間に、他のIDTが配置される。カスケード接続されていない他のIDTは、

弾性波フィルタの入力端子又は出力端子となる。従来はどのIDTも電極指のピッチは同じであったが、上記構成のようにカスケード接続されたIDTの電極指のピッチが他のIDTの電極指のピッチよりも小さくなると、カスケード接続されたIDTのインピーダンスが小さくなる(正確には、インピーダンスの実部が小さくなる)ので、カスケード接続されたIDTのインピーダンスの実部は小さくなる。これにより、カスケード接続部は、高電圧小電流伝送系から低電圧大電流伝送系へと変化する。

[0027] インピーダンス実部の大きな伝送系、すなわち高電圧小電流伝送系と比較して、インピーダンス実部の小さな伝送系、すなわち低電圧大電流伝送系は、寄生容量の影響を受けにくい。なぜなら、低電圧伝送系になることにより、寄生容量に印加される電圧が小さくなるから、寄生容量に流出する電流が小さくなる。加えて、大電流伝送系になることにより、同じ量の電流が寄生容量に流出する場合でも、伝送電流そのものが増えているから、その影響が小さくなるからである。

[0028] したがって、上記構成によれば、カスケード接続部における寄生容量の影響が小さくなり、これに起因するインピーダンスの不整合も小さくなる。この結果、カスケード接続部での信号反射が小さくなり、弾性波フィルタのVSWRが改善される。

[0029] 好ましくは、前記縦結合共振子型弾性波フィルタは、いずれも、カスケード接続された前記IDTの電極指のピッチが他の前記IDTの電極指のピッチよりも小さい。

[0030] カスケード接続されたIDTのインピーダンスをすべて小さくすることにより、弾性波フィルタのVSWRをより改善することできる。

[0031] 具体的には、以下のように構成する。

[0032] 好ましくは、前記圧電基板の比誘電率が30以上である。

[0033] 比誘電率が30以上である圧電基板では、寄生容量が大きくなるため、VSWRの改善効果が顕著である。

[0034] 好ましくは、通過帯域の中心周波数が500MHz以上である。

[0035] 通過帯域の中心周波数が500MHz以上のフィルタにおいて、VSWRの改善効果が顕著である。

[0036] 好ましくは、前記IDTは、弾性表面波の伝搬方向を揃えて一列に配置される。

[0037] この場合、弾性波フィルタは、圧電基板の表面を伝搬する弾性表面波を利用する

弾性表面波フィルタである。

[0038] 好ましくは、前記圧電基板とは弾性定数又は密度が異なる薄膜をさらに備える。前記IDTは、前記圧電基板と前記薄膜との間に弾性境界波の伝搬方向を揃えて一列に配置される。

[0039] この場合、弾性波フィルタは、圧電基板と固体層である薄膜の境界を伝搬する弾性境界波を利用する弾性境界波フィルタである。

[0040] また、本発明は、上記各構成の弾性波フィルタを用いたことを特徴とする通信機を提供する。

発明の効果

[0041] 本発明の弾性波フィルタは、入出力端のVSWRを改善することができる。また、本発明の通信機は、VSWRが改善された弾性波フィルタを備えるので、特性が向上する。

図面の簡単な説明

[0042] [図1]弾性表面波フィルタの構成図(従来例)

[図2]弾性表面波フィルタの構成図(従来例)

[図3]弾性表面波フィルタの構成図(実施例)

[図4]弾性表面波フィルタの特性を示すグラフ(実施例、従来例)

符号の説明

[0043] 350 弾性表面波フィルタ(弾性波フィルタ)

302, 303, 304 IDT

306 縦結合共振子型弾性表面波フィルタ素子(縦結合共振子型弾性波フィルタ)

308, 309, 310 IDT

312 縦結合共振子型弾性表面波フィルタ素子(縦結合共振子型弾性波フィルタ)

発明を実施するための最良の形態

[0044] 以下、本発明の実施の形態として実施例を、図3及び図4を参照しながら説明する。

[0045] 図3に、本発明の実施例である不平衡信号－平衡信号変換機能付の弾性表面波

フィルタ350の構成を示す。なお、図3は模式図であり、反射電極や電極指の本数は実際よりも少なく図示しているが、隣接する反射器やIDTの間の極性関係は正確に図示している。

[0046] 弾性表面波フィルタ350は、従来例として図2に示した弾性表面波フィルタ250と略同様に構成されており、基本的な動作原理は同じである。

[0047] すなわち、弾性表面波フィルタ350は、圧電基板300上に、2つの縦結合共振子型弾性表面波フィルタ素子306, 312、配線313〜321、パッド323〜331(328なし)が形成されている。

[0048] 縦結合共振子型弾性表面波フィルタ素子306, 312は、それぞれ、2つの反射器301, 305;307, 311の間に、3つのIDT302, 303, 304;308, 309, 310が、弾性表面波の伝搬方向を揃えて一列に配置されている。

[0049] 一方の縦結合共振子型弾性表面波フィルタ素子306の中央のIDT303の両端は、それぞれ、配線316, 322によってパッド329, 325に接続されている。他方の縦結合共振子型弾性表面波フィルタ素子312の中央のIDT309は、対向する櫛型電極の一方が2つに分割され、それぞれ、配線319, 320によってパッド330, 331に接続されている。

[0050] 一方の縦結合共振子型弾性表面波フィルタ素子306の両側のIDT302, 304の一端と、他方の縦結合共振子型弾性表面波フィルタ素子312の両側のIDT308, 310の一端とは、配線313, 314によって接続されている。これによって、縦結合共振子型弾性表面波フィルタ素子306, 312は、カスケード接続されている。縦結合共振子型弾性表面波フィルタ素子306, 312の両側のIDT302, 304;308, 310の他端は、それぞれ、配線315, 317;318, 321によって、パッド323, 324;326, 327に接続されている。IDT302とIDT304の極性が反転されている。また、IDT308とIDT310の極性も反転されている。

[0051] パッド323〜327を接地して、パッド329に入力不平衡信号を入力すると、パッド330, 331に出力平衡信号が発生する。

[0052] 次に、図2の弾性表面波フィルタ250と異なる点について、説明する。

[0053] 弾性表面波フィルタ350は、一方の縦結合共振子型弾性表面波フィルタ306にお

いて、カスケード接続されたIDT302，304の電極指のピッチが、他のIDT303の電極指のピッチよりも狭くなっている。同様に、他方の縦結合共振子型弾性表面波フィルタ312において、カスケード接続されたIDT308，310の電極指のピッチが、他のIDT309の電極指のピッチよりも狭くなっている。

[0054] このように電極指ピッチを狭くして、カスケード接続部のインピーダンスを下げることにより、カスケード接続配線を流れる電流が大きくなり、また、カスケード接続配線の電圧が小さくなり、カスケード接続配線に入っている寄生容量の影響が小さくなる。この結果、カスケード接続部におけるインピーダンス不整合が小さくなり、弾性波フィルタ350のVSWR特性を改善することができる。

[0055] 弾性表面波フィルタ350は、例えば、通過帯域の中心周波数が500MHz以上のバンドパスフィルタとして、携帯型通信機に好適に使用することができる。

[0056] 以下に、弾性表面波フィルタ350の具体的な設計パラメータを例示する。

[0057] 圧電基板300として、$LiTaO_3$の36°Y軸回転X方向表面波伝播の単結晶板を用いる。圧電基板300は、36°に限らず、34～44°程度のカット角の$LiTaO_3$を用いてもよい。厚み349nmのアルミニウム薄膜パターンによって、2つの縦結合共振子型弾性表面波フィルタ素子306，312などを形成する。

[0058] 一方の縦結合共振子型弾性表面波フィルタ素子306の設計パラメータは以下のとおりである。

[0059] 交叉幅は135μmである。反射器301，305は、ピッチ2．128μm、メタライズ比0．687のグレーティングであり、その本数は反射器301，305ともに60本である。IDT302，304は、ピッチ2．108μm、メタライズ比0．687であり、その電極指本数はIDT302，304ともに27本である。ただし、IDT302，IDT304とも、IDT303に隣接する電極指4本は、ピッチ1．941μm、メタライズ比0．687となっている。IDT303は、ピッチ2．117μm、メタライズ比0．684であり、その電極指本数は36本である。ただし、IDT303の両端各4本の電極指は、ピッチ1．941μm、メタライズ比0．687となっている。反射器301とIDT302の間隔（電極指中心間隔）は2．085μmであり、反射器305とIDT304の間隔（電極指中心間隔）も同じく2．085μmである。IDT302とIDT303の間隔（電極指中心間隔）は1．940μmであり、IDT304とIDT303の間

隔(電極指中心間隔)も同じく1．940μmである。IDT302，304のコンダクタンスピークの周波数はIDT303のコンダクタンスピークの周波数より高い。

[0060] 他方の縦結合共振子型弾性表面波フィルタ素子312の設計パラメータは、以下の通りである。

[0061] 交叉幅は135μmである。反射器307，311は、ピッチ2．128μm、メタライズ比0．687のグレーティングであり、その本数は反射器307，311ともに60本である。IDT308，310は、ピッチ2．108μm、メタライズ比0．687であり、その電極指本数はIDT308，310ともに27本である。ただし、IDT308，310とも、IDT309に隣接する電極指4本は、ピッチ1．957μm、メタライズ比0．682となっている。IDT309は、ピッチ2．117μm、メタライズ比0．684であり、その電極指本数は40本である。ただし、IDT309の両端各5本の電極指は、ピッチ1．941μm、メタライズ比0．687となっている。反射器307とIDT308の間隔(電極指中心間隔)は2．085μmであり、反射器311とIDT310の間隔(電極指中心間隔)も同じく2．085μmである。IDT308とIDT309の間隔(電極指中心間隔)は1．940μmであり、IDT310とIDT309の間隔(電極指中心間隔)も同じく1．940μmである。IDT308，310のコンダクタンスピークの周波数はIDT309のコンダクタンスピークの周波数より高い。

[0062] なお、カスケード接続されたIDT302，304;308，310の電極指ピッチは、入出力端子に接続された他のIDT303;309の電極指ピッチに対して、適宜な比率で小さくすればよいが、特に、0．995～0．850の比率で小さくすることが好ましい。VSWRの改善のためには0．995以下の比率にすればよく、弾性表面波フィルタの特性などに悪影響が出ないようにするためには0．850以上の比率とすればよい。

[0063] 図4に、実施例と従来例の弾性表面波フィルタの特性を示す。図4(a)は挿入損失、図4(b)は入力側のVSWR、図4(c)は出力側のVSWRである。ここで、実施例は、上記の具体的な設計パラメータの弾性表面波フィルタ350であり、図4において、その特性を細線で示している。従来例は、実施例の弾性表面波フィルタ350のIDT303の電極指ピッチとIDT302，304の電極指ピッチを同じ2．108μmにして、IDT309の電極ピッチとIDT308，310の電極指ピッチを同じ2．108μmにした以外は実施例と同じであり、図4において、その特性を太線で示している。

[0064] 両者のVSWRを比較すると、実施例の弾性表面波フィルタの方が、従来例の弾性表面波フィルタよりも、通過帯域内の大部分の周波数において、VSWRが小さくなっている(改善されている)ことがわかる。特に、従来例の弾性表面波フィルタにおいて最も大きかった通過帯域低周波端での入力側VSWRは、実施例の弾性表面波フィルタにおいては大幅に小さくなっている。

[0065] なお、周波数935MHz付近においては、従来例の弾性表面波フィルタのVSWRの方が、実施例の弾性表面波フィルタのVSWRよりも小さくなっている。これは、周波数935MHz付近においては、カスケード接続配線とアースパターンの間の寄生容量が、カスケード接続点におけるインピーダンス整合を助ける方向に働いていたため、実施例では、その寄生容量の働きを阻害した結果、逆にカスケード接続点におけるインピーダンス整合が悪化してしまったからである。帯域内のある周波数領域においては、カスケード接続配線とアースパターンの間の寄生容量が、カスケード接続点におけるインピーダンス整合を助けていることもあるため、電極指ピッチを小さくしても、必ずしも、帯域内の全周波数においてVSWRが改善するとは限らない。しかしながら、カスケード接続線とアースパターンの間の寄生容量は一般的に過剰であり、帯域内のほとんどの周波数領域においては、カスケード接続点におけるインピーダンス整合を悪化させる要因となっている。

[0066] したがって、実施例のように電極ピッチを狭くすれば、帯域内の多くの部分において、VSWRを小さくする効果があり、全体として見れば、VSWRは改善される。

[0067] 使用する圧電基板の比誘電率が大きければ大きいほど、また、通過帯域の周波数が高ければ高いほど、カスケード接続線とアースパターンの間の寄生容量の影響が強くなりすぎる傾向があるので、実施例のように電極指ピッチを狭くすることが、VSWRの改善に有効である。

[0068] なお、本発明は上記実施例に限定されるものではなく、種々の態様で実施可能である。

請求の範囲

[1] 圧電基板上に弾性波の伝搬方向に沿って形成された3つのIDTをそれぞれ含む2つの縦結合共振子型弾性波フィルタがカスケード接続された弾性波フィルタにおいて、

前記縦結合共振子型弾性波フィルタの少なくとも一方は、カスケード接続された前記IDTの電極指のピッチがカスケード接続された前記IDTのコンダクタンスピークの周波数が他の前記IDTのコンダクタンスピークの周波数より高くなるように、他の前記IDTの電極指のピッチよりも小さくされていることを特徴とする弾性波フィルタ。

[2] 前記縦結合共振子型弾性波フィルタは、いずれも、カスケード接続された前記IDTの電極指のピッチが他の前記IDTの電極指のピッチよりも小さいことを特徴とする、請求項1に記載の弾性波フィルタ。

[3] 前記圧電基板の比誘電率が30以上であることを特徴とする、請求項1又は2に記載の弾性波フィルタ。

[4] 通過帯域の中心周波数が500MHz以上であることを特徴とする、請求項1又は2に記載の弾性波フィルタ。

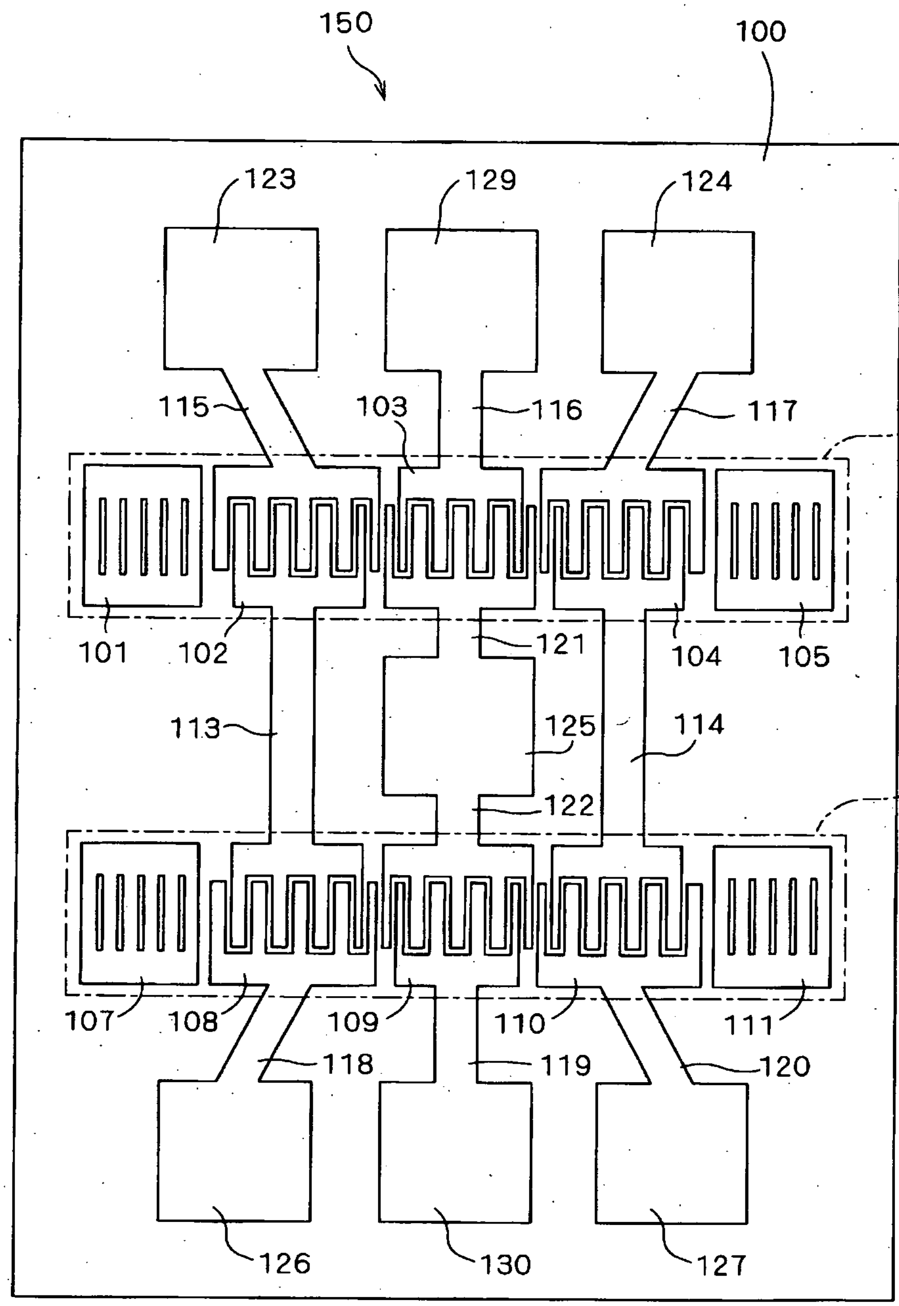
[5] 前記IDTは、それぞれ、弾性表面波の伝搬方向を揃えて一列に配置されたことを特徴とする、請求項1乃至4のいずれか一つに記載の弾性波フィルタ。

[6] 前記圧電基板上に形成され、該圧電基板とは弾性定数又は密度が異なる薄膜をさらに備え、

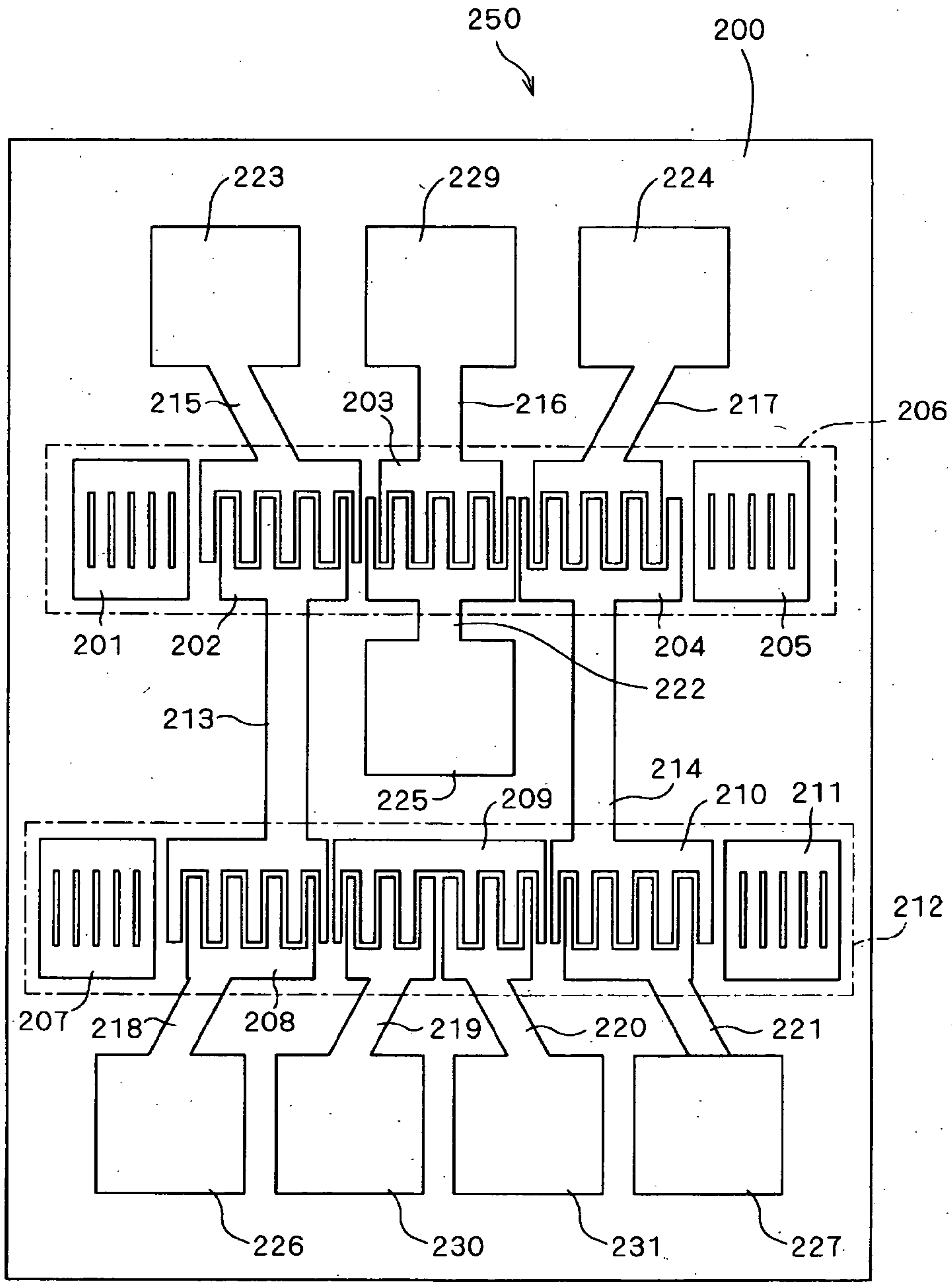
前記IDTは、それぞれ、前記圧電基板と前記薄膜との間に弾性境界波の伝搬方向を揃えて一列に配置されたことを特徴とする、請求項1乃至4のいずれか一つに記載の弾性波フィルタ。

[7] 請求項1乃至6に記載の弾性波フィルタを用いたことを特徴とする通信機。

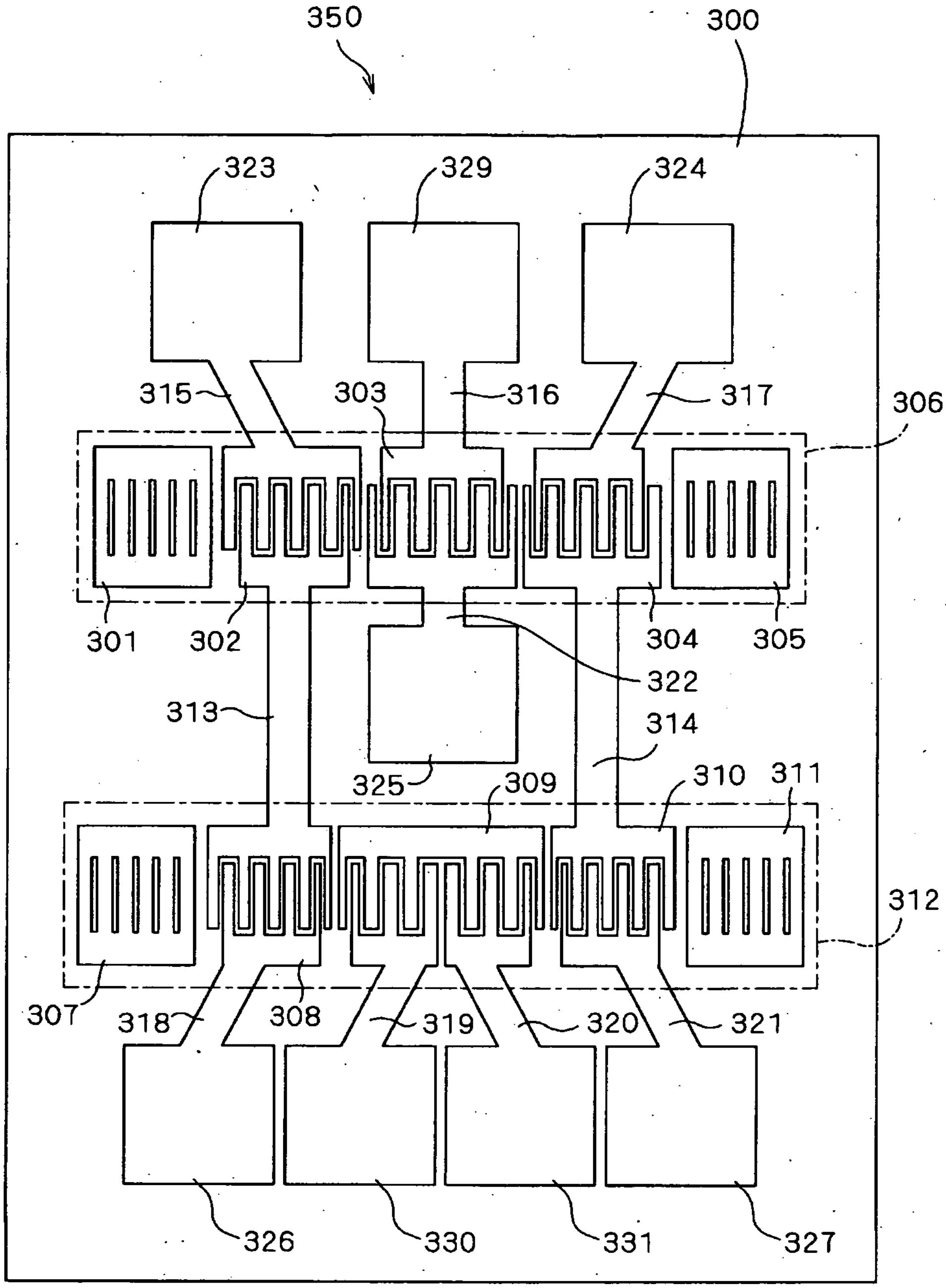
[図1]


150
100
123
129
124
115
103
116
117
106
101
102
121
104
105
113
125
114
112
122
107
108
109
110
111
118
119
120
126
130
127

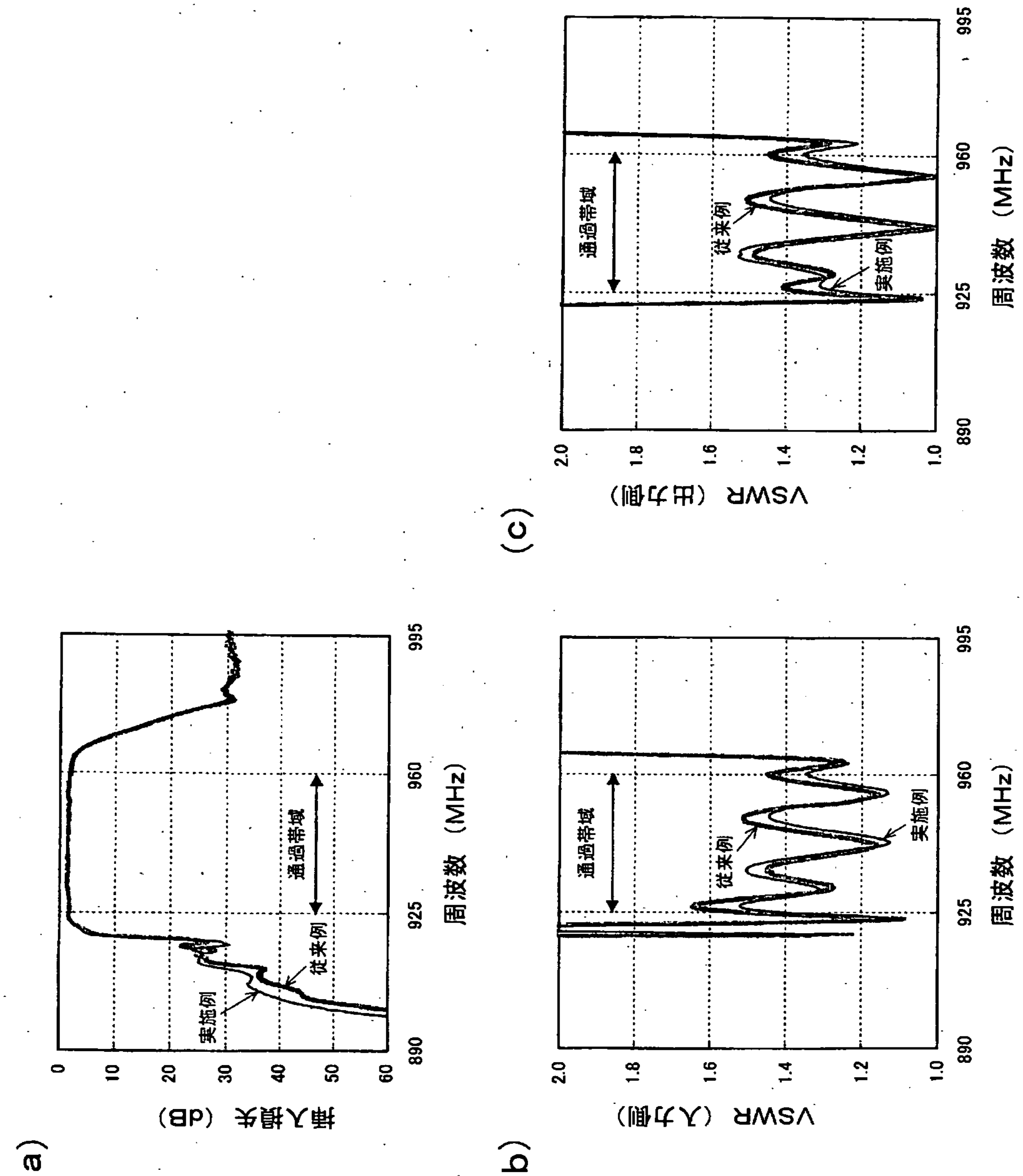
[図2]


250
200
223
229
224
215
203
216
217
206
201
202
204
205
222
213
225
214
209
210
211
212
207
218
208
219
220
221
226
230
231
227

[図3]


350
300
323
329
324
315
303
316
317
306
301
302
304
305
322
313
314
325
309
310
311
312
307
318
308
319
320
321
326
330
331
327

[図4]


(a)
挿入損失 (dB)
0
10
20
30
40
50
60
890
925
960
995
周波数 (MHz)
通過帯域
実施例
従来例
(b)
VSWR (入力側)
2.0
1.8
1.6
1.4
1.2
1.0
890
925
960
995
周波数 (MHz)
通過帯域
従来例
実施例
(c)
VSWR (出力側)
2.0
1.8
1.6
1.4
1.2
1.0
890
925
960
995
周波数 (MHz)
通過帯域
従来例
実施例

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/006609

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] H03H9/64, 9/145

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[7] H03H3/08-3/10, 9/145, 9/25, 9/42-9/44, 9/64, 9/68, 9/72, 9/76

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Kokai Jitsuyo Shinan Koho	1971-2005	Toroku Jitsuyo Shinan Koho	1994-2005

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2003-92527 A (Matsushita Electric Industrial Co., Ltd.), 28 March, 2003 (28.03.03), Par. Nos. [0033] to [0062]; Figs. 1, 3 & JP 2004-336824 A & US 2003/0030511 A1 & US 2004/0095207 A & EP 001276235 A1 & CN 001398049 A	1-2,4-5,7 1-5,7
Y	JP 2000-091881 A (Toyo Communication Equipment Co., Ltd.), 31 March, 2000 (31.03.00), Claim 5; Par. Nos. [0007] to [0014]; Fig. 3 (Family: none)	1-5,7

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search 07 July, 2005 (07.07.05)	Date of mailing of the international search report 19 July, 2005 (19.07.05)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/006609

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2002-084165 A (Murata Mfg. Co., Ltd.), 22 March, 2002 (22.03.02), Full text; Figs. 1, 10 & US 2001/0043024 A1 & US 2004/0124740 A & EP 001168612 A2 & CN 001331513 A	1-5,7
Y	JP 2003-258603 A (Murata Mfg. Co., Ltd.), 12 September, 2003 (12.09.03), Par. No. [0050] & US 2003/0117239 A1 & EP 001324490 A2 & CN 001431774 A	3,5,7

English translation of the Japanese priority document

[Name of Document] Application for Patent
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[Addressee] Commissioner of the Patent Office
[Int. Cl.] H03H 9/15
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[Application Fees]
[Prepayment Registration No.] 209898

[Amount of Payment]	16000	
[List of Documents Attached]		
[Name of Document]	Claims	1
[Name of Document]	Specification	1
[Name of Document]	Drawings	1
[Name of Document]	Abstract	1

[Name of Document] CLAIMS

[Claim 1]

An elastic-wave filter comprising two longitudinally-coupled-resonator-type elastic-wave filter elements that are cascade-connected with each other, each longitudinally-coupled-resonator-type elastic-wave filter element including three IDTs arranged on a piezoelectric substrate in a transmitting direction of an elastic wave,

wherein, in at least one of the longitudinally-coupled-resonator-type elastic-wave filter elements, electrode fingers of one or two of the IDTs that are cascade-connected are arranged at a pitch that is smaller than a pitch of electrode fingers of the remaining IDT(s) such that a conductance peak in said one or two of the cascade-connected IDTs is higher than a conductance peak in the remaining IDT(s).

[Claim 2]

The elastic-wave filter according to Claim 1, wherein in each of the longitudinally-coupled-resonator-type elastic-wave filter elements, electrode fingers of one or two of the IDTs that are cascade-connected are arranged at a pitch that is smaller than a pitch of electrode fingers of the remaining IDT(s).

[Claim 3]

The elastic-wave filter according to one of Claims 1

and 2, wherein a relative dielectric constant of the piezoelectric substrate is set at 30 or more.

[Claim 4]

The elastic-wave filter according to one of Claims 1 and 2, wherein a center frequency of a passband is set at 500 MHz or more.

[Claim 5]

The elastic-wave filter according to any one of Claims 1 to 4, wherein the IDTs are aligned in a transmitting direction of a surface acoustic wave.

[Claim 6]

The elastic-wave filter according to any one of Claims 1 to 4, further comprising a thin film which is disposed on the piezoelectric substrate and has an elastic constant or a density that is different from that of the piezoelectric substrate,

wherein the IDTs are aligned in a transmitting direction of an elastic boundary wave between the piezoelectric substrate and the thin film.

[Claim 7]

A communication device comprising the elastic-wave filter according to one of Claims 1 to 6.

[Name of Document] SPECIFICATION

[Title of the Invention] ELASTIC-WAVE FILTER AND COMMUNICATION DEVICE EQUIPPED WITH THE ELASTIC-WAVE FILTER

[Technical Field]

[0001]

The present invention relates to elastic-wave filters and communication devices equipped with such elastic-wave filters. In particular, the present invention relates to an elastic-wave filter that applies elastic waves, such as a surface acoustic wave filter and an elastic boundary wave filter, and to a communication device equipped with such an elastic-wave filter.

[Background Art]

[0002]

As an example of a bandpass filter having passband frequency ranging from several tens of MHz to several GHz, a surface acoustic wave filter is known. Due to having a compact, lightweight structure, surface acoustic wave filters are used in portable communication devices in recent years.

[0003]

Although there are various types of surface acoustic wave filters, the type commonly used in a front end of a portable communication device is a longitudinally-coupled-

resonator-type surface-acoustic-wave filter having two reflectors arranged on a piezoelectric substrate in a transmitting direction of a surface acoustic wave and also having input IDTs and output IDTs arranged alternately between the two reflectors. The longitudinally-coupled-resonator-type surface-acoustic-wave filter is characterized in that the insertion loss in the frequency within a band is small and that the conversion between balanced signals and unbalanced signals can be achieved readily.

[0004]

The principle of operation in the longitudinally-coupled-resonator-type surface-acoustic-wave filter is as follows.

[0005]

An input electric signal is converted to a surface acoustic wave by the input IDTs so that a standing wave of the surface acoustic wave is generated between the two reflectors. The energy of the generated standing wave is converted to an electric signal by the output IDTs so that an output signal is generated. In this case, the conversion efficiency between the electric signal and the surface acoustic wave in the input IDTs and the output IDTs has a frequency characteristic, and moreover, the surface-acoustic-wave reflection efficiency of the reflectors also has a frequency characteristic. Thus, the longitudinally-

coupled-resonator-type surface-acoustic-wave filter has a bandpass characteristic that only transmits signals that are within a certain frequency range.

[0006]

In order to increase the amount of signal attenuation outside the passband, a surface acoustic wave filter is used, which has two or more longitudinally-coupled-resonator-type surface-acoustic-wave filter elements that are cascade-connected to each other on a piezoelectric substrate. By cascade-connecting multiple longitudinally-coupled-resonator-type surface-acoustic-wave filter elements, the signals outside the passband are sequentially attenuated by the corresponding longitudinally-coupled-resonator-type surface-acoustic-wave filter element, whereby the amount of signal attenuation outside the passband is increased (see, for example, Patent Document 1).

[0007]

Fig. 1 illustrates a surface acoustic wave filter 150 having two longitudinally-coupled-resonator-type surface-acoustic-wave filter elements 106, 112 disposed on a piezoelectric substrate 100 and cascade-connected to each other.

[0008]

The longitudinally-coupled-resonator-type surface-acoustic-wave filter element 106 includes two reflectors 101,

105 between which three IDTs 102, 103, 104 are aligned in a transmitting direction of a surface acoustic wave. Similarly, the longitudinally-coupled-resonator-type surface-acoustic-wave filter element 112 includes two reflectors 107, 111 between which three IDTs 108, 109, 110 are aligned in a transmitting direction of a surface acoustic wave. The reflectors 101, 105, 107, 111 are periodical gratings. The IDTs 102 to 104, 108 to 110 are interdigitating comb-shaped electrodes.

[0009]

The IDT 102 and the IDT 108 are connected to each other via a wire 113, and the IDT 104 and the IDT 110 are connected to each other via a wire 114, whereby the longitudinally-coupled-resonator-type surface-acoustic-wave filter elements 106, 112 are cascade-connected to each other.

[0010]

Wires 115 to 122 are provided as conductors between pads 123 to 130 (128 not included) and the IDTs 102 to 104, 108 to 110. The pads 123 to 127 function as grounding pads that are grounded. On the other hand, the pad 129 functions as an input pad to which an input voltage is applied. The pad 130 functions as an output pad in which an output voltage is generated.

[0011]

The reflectors 101, 105, 107, 111, the IDTs 102 to 104,

108 to 110, the wires 113 to 122, and the pads 123 to 130 (128 not included) together define a metallic film pattern provided on the piezoelectric substrate 100. The metallic film pattern is formed by a thin-film micromachining process, which may be, for example, a vacuum film-forming process, a photolithography process, an etching process, or a lift-off process.

[0012]

Fig. 2 illustrates a surface acoustic wave filter 250 which is provided with a function for conversion between an unbalanced signal and a balanced signal and has two longitudinally-coupled-resonator-type surface-acoustic-wave filter elements 206, 212 disposed on a piezoelectric substrate 200 and cascade-connected to each other. Since the surface acoustic wave filter 250 and the surface acoustic wave filter 150 share many common features, the differences from the surface acoustic wave filter 150 will be mainly described below.

[0013]

An IDT 209 is divided into two IDT segments. The IDT 209 generates a balanced signal. Pads 223 to 227 are grounded. When an unbalanced input signal is input to a pad 229, balanced output signals are generated in a pad 230 and a pad 231.

[0014]

In the surface acoustic wave filter 250, the polarities of an IDT 202 and an IDT 204 are inverted, and the polarities of an IDT 208 and an IDT 210 are also inverted. Thus, a connection wire 213 and a connection wire 214 transmit reversed phase signals. This technique is effective for improving the degree of balance of the balanced output signals of the surface acoustic wave filter 250. Alternatively, the function for conversion between an unbalanced signal and a balanced signal in the surface acoustic wave filter 250 can be sufficiently achieved without using this technique. In that case, the IDT 202 and the IDT 204 are given the same polarity and the IDT 208 and the IDT 210 are also given the same polarity so that the connection wire 213 and the connection wire 214 transmit in-phase signals. However, using the above-mentioned technique is advantageous in that the degree of balance of the balanced output signals is improved.

[0015]

Examples of surface acoustic wave filters have just been described above. As a similar filter, an elastic boundary wave filter is known. Similar to surface acoustic wave filters, an elastic boundary wave filter includes reflectors and IDTs composed of a metallic film disposed on a piezoelectric substrate. For example, the elastic boundary wave filter has filter electrodes including IDTs

and reflectors composed of, for example, Al on a surface of a piezoelectric single-crystal plate, and a film having a sufficient thickness and composed of, for example, SiO_2 on the filter electrodes. The film has an elastic constant or density that is different from that of the piezoelectric single-crystal. Although the operation and the structure are substantially the same as those of surface acoustic wave filters, the elastic boundary wave filter additionally has a solid layer disposed over the surface of the piezoelectric substrate. The elastic boundary wave filter operates based on interaction between the LDTs and an elastic wave (elastic boundary wave) transmitted through the boundary between the piezoelectric substrate and the solid layer. In contrast to the surface acoustic wave filter which requires a package having a cavity to prevent the surface of the substrate from being restrained, the elastic boundary wave filter is advantageous in that it does not require such a package having a cavity since the wave is transmitted through the boundary plane between the piezoelectric single-crystal substrate and the film.

[0016]

In short, a surface acoustic wave filter operates based on a transmission of a surface acoustic wave through a surface of a piezoelectric substrate, whereas an elastic boundary wave filter operates based on a transmission of an

elastic boundary wave through a boundary between a piezoelectric substrate and a solid layer. The principle of operation of the two is basically the same, and the design approach of the two is similar.

[0017]

In the specification and claims of the present invention, the term "elastic-wave filter" will be used as a generic term to refer to a filter, such as the surface acoustic wave filter and the elastic boundary wave filter, which applies an elastic wave (e.g. Rayleigh wave, SH wave, pseudo surface acoustic wave, Love wave, Sezawa wave, Stonely wave, boundary wave). Furthermore, the term "longitudinally-coupled-resonator-type elastic-wave filter" will be used as a generic term to refer to a longitudinally-coupled-resonator-type surface-acoustic-wave filter and a longitudinally-coupled-resonator-type elastic-boundary-wave filter.

[Patent Document 1] Japanese Unexamined Patent Application Publication No. 2002-9587

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0018]

High-frequency bandpass filters like the elastic-wave filters require good impedance matching. A filter having bad impedance matching in the input-output terminals, that

is, a filter having large signal reflection in the input-output terminals, is subject to bad (large) insertion loss since the signals are lost due to reflection. Moreover, the signals reflected in the input-output terminals of the filter re-enter other electronic components connected to the filter, which could lead to failures, such as a transmission error of a circuit.

[0019]

The terms "good impedance matching", "small signal reflection", and "small VSWR (voltage standing wave ratio)" are all used synonymously with one another. If the impedance matching is good, the signal reflection is smaller and the VSWR is also smaller. A small VSWR implies that the signal reflection is small, which means that the impedance matching is good.

[0020]

In an elastic-wave filter having a plurality of cascade-connected longitudinally-coupled-resonator-type elastic-wave filter elements disposed on a piezoelectric substrate, the impedance matching in the cascade-connected portion between the longitudinally-coupled-resonator-type elastic-wave filter elements affects the impedance matching of the entire elastic-wave filter. Specifically, if the impedance matching in the cascade-connected portion between the longitudinally-coupled-resonator-type elastic-wave

filter elements is bad, and if signal reflection occurs in this cascade-connected portion, the reflected signal is released outward from the filter as a reflection wave of the elastic-wave filter.

[0021]

Concerning the cascade-connected portion between the longitudinally-coupled-resonator-type elastic-wave filter elements, the impedance of one of the longitudinally-coupled-resonator-type elastic-wave filter elements with respect to the cascade-connected portion and the impedance of the other longitudinally-coupled-resonator-type elastic-wave filter element with respect to the cascade-connected portion ideally have a complex conjugate relationship. If the two have a complex conjugate relationship, the impedance matching in the cascade-connected portion is complete, meaning that signal reflection in this portion will not occur at all.

[0022]

However, under present circumstances, the impedances of the longitudinally-coupled-resonator-type elastic-wave filter elements with respect to the cascade-connected portion tend to become capacitive (i.e. the imaginary impedances become negative) due to the parasitic capacitance between cascade-connected wires and a grounding pattern, meaning that an ideal complex conjugate state (in which one

of the imaginary impedances is positive and the other imaginary impedance is negative) is difficult to attain. This is the factor that increases the signal reflection in the cascade-connected portion between the longitudinally-coupled-resonator-type elastic-wave filter elements. As a result, the VSWR characteristic of an elastic-wave filter having cascaded-connected longitudinally-coupled-resonator-type elastic-wave filter elements is deteriorated. This problem is more noticeable in a case where the piezoelectric substrate used has a large relative dielectric constant since the parasitic capacitance between the cascade-connected wires and the grounding pattern increases in proportion to the relative dielectric constant. Moreover, this problem becomes more noticeable as the frequency within the passband of the filter becomes higher since the current flowing into the parasitic capacitance increases in proportion to the frequency within the passband.

[0023]

Accordingly, it is an object of the present invention to provide an elastic-wave filter having a plurality of cascade-connected longitudinally-coupled-resonator-type elastic-wave filter elements disposed on a piezoelectric substrate, in which an adverse effect of a parasitic capacitance in cascade-connected wires disposed between the longitudinally-coupled-resonator-type elastic-wave filter

elements is reduced so as to improve impedance matching of a cascade-connected portion and to improve the VSWR characteristics of input-output terminals of the elastic-wave filter.

[Means for Solving the Problems]

[0024]

In order to achieve the aforementioned object, the present invention provides an elastic-wave filter having the following structure.

[0025]

An elastic-wave filter includes two longitudinally-coupled-resonator-type elastic-wave filter elements that are cascade-connected with each other, each longitudinally-coupled-resonator-type elastic-wave filter element including three IDTs arranged on a piezoelectric substrate in a transmitting direction of an elastic wave. In at least one of the longitudinally-coupled-resonator-type elastic-wave filter elements, electrode fingers of one or two of the IDTs that are cascade-connected are arranged at a pitch that is smaller than a pitch of electrode fingers of the remaining IDT(s) such that a conductance peak in said one or two of the cascade-connected IDTs is higher than a conductance peak in the remaining IDT(s).

[0026]

According to the structure described above, in each of

the longitudinally-coupled-resonator-type elastic-wave filter elements, the cascade-connected IDT(s) generally have the remaining IDT(s) disposed therebetween. The remaining IDT(s) not cascade-connected serves as an input terminal or an output terminal of the elastic-wave filter. Conventionally, the electrode fingers were arranged at the same pitch for all IDTs. In contrast, the electrode fingers of one or two of the cascade-connected IDTs are arranged at a pitch that is smaller than the pitch of the electrode fingers of the remaining IDT(s) in the structure described above. Since this reduces the impedance of the cascade-connected IDT(s) (to be precise, the real impedance becomes smaller), the real impedance of the cascade-connected IDT(s) becomes smaller. Accordingly, the cascade-connected portion changes from a high-voltage low-current transmission system to a low-voltage high-current transmission system.

[0027]

In comparison with a transmission system having a large real impedance, namely, a high-voltage low-current transmission system, a transmission system having a small real impedance, namely, a low-voltage high-current transmission system, is less affected by parasitic capacitance. This is due to the following reasons. Specifically, since the transmission system is a low-voltage transmission system, a lower voltage is applied to the

parasitic capacitance, whereby the current flowing into the parasitic capacitance is reduced. In addition, since the transmission system is a high-current transmission system, even if the same amount of current flows into the parasitic capacitance, the effect of the parasitic capacitance is still reduced since the transmitted current itself increases.

[0028]

Accordingly, the effect of the parasitic capacitance in the cascade-connected portion is reduced, whereby the mismatch of the impedance caused by the effect is reduced. As a result, this reduces the signal reflection in the cascade-connected portion, whereby the VSWR characteristic of the elastic-wave filter is improved.

[0029]

Furthermore, in each of the longitudinally-coupled-resonator-type elastic-wave filter elements, electrode fingers of one or two of the IDTs that are cascade-connected are preferably arranged at a pitch that is smaller than a pitch of electrode fingers of the remaining IDT(s).

[0030]

By reducing the impedance of all of the cascade-connected IDTs, the VSWR characteristic of the elastic-wave filter can be further improved.

[0031]

Specifically, this may be achieved by the following

structure.

[0032]

A relative dielectric constant of the piezoelectric substrate is preferably set at 30 or more.

[0033]

In a piezoelectric substrate whose relative dielectric constant is 30 or more, the parasitic capacitance is increased, thereby achieving an outstanding improvement in the VSWR characteristic.

[0034]

Furthermore, a center frequency of a passband is preferably set at 500 MHz or more.

[0035]

In a filter whose center frequency of a passband is set at 500 MHz or more, an improvement in the VSWR characteristic is outstanding.

[0036]

Furthermore, the IDTs are preferably aligned in a transmitting direction of a surface acoustic wave.

[0037]

In this case, the elastic-wave filter is a surface acoustic wave filter that utilizes a surface acoustic wave transmitted through the surface of the piezoelectric substrate.

[0038]

Furthermore, the elastic-wave filter may further include a thin film which is disposed on the piezoelectric substrate and has an elastic constant or a density that is different from that of the piezoelectric substrate. Moreover, the IDTs are preferably aligned in a transmitting direction of an elastic boundary wave between the piezoelectric substrate and the thin film.

[0039]

In this case, the elastic-wave filter is an elastic boundary wave filter that utilizes an elastic boundary wave transmitted through a boundary between the piezoelectric substrate and a thin film defining a solid layer.

[0040]

Furthermore, the present invention provides a communication device equipped with the elastic-wave filter having the structure described above.

[Advantages]

[0041]

According to an elastic-wave filter of the present invention, the VSWR characteristics in input-output terminals are improved. Furthermore, a communication device of the present invention is provided with the elastic-wave filter having improved VSWR characteristics so that the feature of the device is improved.

[Best Mode for Carrying Out the Invention]

[0042]

An embodiment of the present invention will now be described with reference to Figs. 3 and 4.

[0043]

Fig. 3 illustrates a surface acoustic wave filter 350 according to the embodiment of the present invention, which is provided with a function for conversion between an unbalanced signal and a balanced signal. Specifically, Fig. 3 is a schematic diagram in which the number of reflecting electrodes and electrode fingers shown is less than the actual quantity. However, the polarity relationships between adjacent reflectors and IDTs are accurately illustrated.

[0044]

The surface acoustic wave filter 350 has substantially the same structure as the surface acoustic wave filter 250 shown in Fig. 2 as a conventional example, and has basically the same principle of operation.

[0045]

In other words, the surface acoustic wave filter 350 includes a piezoelectric substrate 300 on which two longitudinally-coupled-resonator-type surface-acoustic-wave filter elements 306, 312, wires 313 to 321, and pads 323 to 331 (328 not included) are provided.

[0046]

The longitudinally-coupled-resonator-type surface-acoustic-wave filter element 306 includes two reflectors 301, 305 between which three IDTs 302, 303, 304 are aligned in a transmitting direction of a surface acoustic wave. On the other hand, the longitudinally-coupled-resonator-type surface-acoustic-wave filter element 312 includes two reflectors 307, 311 between which three IDTs 308, 309, 310 are aligned in a transmitting direction of a surface acoustic wave.

[0047]

Opposite ends of the IDT 303 disposed in the midsection of the longitudinally-coupled-resonator-type surface-acoustic-wave filter element 306 are respectively connected to the pads 329, 325 via wires 316, 322. On the other hand, the IDT 309 disposed in the midsection of the longitudinally-coupled-resonator-type surface-acoustic-wave filter element 312 has two opposing interdigital electrodes, one of which is divided into two segments. The two segments are respectively connected to the pads 330, 331 via the wires 319, 320.

[0048]

First ends of the IDTs 302, 304 disposed on opposite sides of the longitudinally-coupled-resonator-type surface-acoustic-wave filter element 306 are respectively connected to first ends of the IDTs 308, 310 disposed on opposite

sides of the longitudinally-coupled-resonator-type surface-acoustic-wave filter element 312 via the wires 313, 314. Thus, the longitudinally-coupled-resonator-type surface-acoustic-wave filter elements 306, 312 are cascade-connected to each other. Second ends of the IDTs 302, 304 disposed on opposite sides of the longitudinally-coupled-resonator-type surface-acoustic-wave filter element 306 are respectively connected to the pads 323, 324 via the wires 315, 317, and second ends of the IDTs 308, 310 disposed on opposite sides of the longitudinally-coupled-resonator-type surface-acoustic-wave filter element 312 are respectively connected to the pads 326, 327 via the wires 318, 321. The polarities of the IDT 302 and the IDT 304 are inverted. Moreover, the polarities of the IDT 308 and the IDT 310 are inverted.

[0049]

When an unbalanced input signal is input to the pad 329 in a state where the pads 323 to 327 are grounded, balanced output signals are generated in the pads 330, 331.

[0050]

The differences from the surface acoustic wave filter 250 shown in Fig. 2 will be described below.

[0051]

In the longitudinally-coupled-resonator-type surface-acoustic-wave filter element 306 of the surface acoustic wave filter 350, the electrode fingers of the cascade-

connected IDTs 302, 304 are arranged at a pitch that is narrower than the pitch of electrode fingers of the IDT 303. Similarly, in the longitudinally-coupled-resonator-type surface-acoustic-wave filter element 312, the electrode fingers of the cascade-connected IDTs 308, 310 are arranged at a pitch that is narrower than the pitch of electrode fingers of the IDT 309.

[0052]

By setting the electrode fingers at a narrower pitch, the impedance of the cascade-connected portion is reduced. This increases the current flowing through the cascade-connected wires and decreases the voltage of the cascade-connected wires, thereby reducing the effect of the parasitic capacitance in the cascade-connected wires. As a result, impedance mismatching in the cascade-connected portion is reduced, thereby improving the VSWR characteristics of the surface acoustic wave filter 350.

[0053]

The surface acoustic wave filter 350 may be suitably used in, for example, a portable communication device as a bandpass filter whose center frequency of a passband is 500 MHz or more.

[0054]

Specific design parameters of the surface acoustic wave filter 350 will be described below.

[0055]

The piezoelectric substrate 300 is a $LiTaO_3$ single crystal plate of a 36° Y-cut X-surface-wave-transmission type. The piezoelectric substrate 300 is not limited to 36°, and may alternatively be $LiTaO_3$ with a cut angle of 34° to 44°. The two longitudinally-coupled-resonator-type surface-acoustic-wave filter elements 306, 312 are formed using an aluminum film pattern having a thickness of 349 nm.

[0056]

The design parameters of the longitudinally-coupled-resonator-type surface-acoustic-wave filter element 306 are as follows.

[0057]

The crossover width is 135 µm. Each of the reflectors 301, 305 includes gratings arranged at a pitch of 2.128 µm and having a metallization ratio of 0.687. The number of gratings provided in each of the reflectors 301, 305 is 60. On the other hand, each of the IDTs 302, 304 includes electrode fingers arranged at a pitch of 2.108 µm and having a metallization ratio of 0.687. The number of electrode fingers provided in each of the IDTs 302, 304 is 27. However, in each of the IDT 302 and the IDT 304, four of the electrode fingers that are adjacent to the IDT 303 are arranged at a pitch of 1.941 µm and have a metallization ratio of 0.687. The IDT 303 includes electrode fingers

arranged at a pitch of 2.117 μm and having a metallization ratio of 0.684. The number of electrode fingers provided in the IDT 303 is 36. However, four of the electrode fingers disposed on each side of the IDT 303 are arranged at a pitch of 1.941 μm and have a metallization ratio of 0.687. The reflector 301 and the IDT 302 are separated from each other by a distance of 2.085 μm (i.e. the distance between the centers of electrode fingers). Similarly, the reflector 305 and the IDT 304 are separated from each other by a distance of 2.085 μm (i.e. the distance between the centers of electrode fingers). Furthermore, the IDT 302 and the IDT 303 are separated from each other by a distance of 1.940 μm (i.e. the distance between the centers of electrode fingers). Similarly, the IDT 304 and the IDT 303 are separated from each other by a distance of 1.940 μm (i.e. the distance between the centers of electrode fingers). The conductance peak in each of the IDTs 302, 304 is higher than the conductance peak in the IDT 303.

[0058]

The design parameters of the longitudinally-coupled-resonator-type surface-acoustic-wave filter element 312 are as follows.

[0059]

The crossover width is 135 μm. Each of the reflectors 307, 311 includes gratings arranged at a pitch of 2.128 μm

and having a metallization ratio of 0.687. The number of gratings provided in each of the reflectors 307, 311 is 60. On the other hand, each of the IDTs 308, 310 includes electrode fingers arranged at a pitch of 2.108 and having a metallization ratio of 0.687. The number of electrode fingers provided in each of the IDTs 308, 310 is 27. However, in each of the IDT 308 and the IDT 310, four of the electrode fingers that are adjacent to the IDT 309 are arranged at a pitch of 1.957 µm and have a metallization ratio of 0.682. The IDT 309 includes electrode fingers arranged at a pitch of 2.117 µm and having a metallization ratio of 0.684. The number of electrode fingers provided in the IDT 309 is 40. However, five of the electrode fingers disposed on each side of the IDT 309 are arranged at a pitch of 1.941 µm and have a metallization ratio of 0.687. The reflector 307 and the IDT 308 are separated from each other by a distance of 2.085 µm (i.e. the distance between the centers of electrode fingers). Similarly, the reflector 311 and the IDT 310 are separated from each other by a distance of 2.085 µm (i.e. the distance between the centers of electrode fingers). Furthermore, the IDT 308 and the IDT 309 are separated from each other by a distance of 1.940 µm (i.e. the distance between the centers of electrode fingers). Similarly, the IDT 310 and the IDT 309 are separated from each other by a distance of 1.940 µm (i.e. the distance

between the centers of electrode fingers). The conductance peak in each of the IDTs 308, 310 is higher than the conductance peak in the IDT 309.

[0060]

The pitches of the electrode fingers in the cascade-connected IDTs 302, 304; 308, 310 may respectively be set smaller than the pitches of the electrode fingers in the other IDTs 303; 309, which are connected with input-output terminals, by an appropriate ratio. Specifically, the pitches are set smaller by a ratio preferably within a range of 0.995 to 0.850. In order to improve the VSWR characteristics, the ratio may be set at 0.995 or lower. On the other hand, the ratio may be set at 0.850 or higher in order to prevent, for example, the characteristics of the surface acoustic wave filter from being adversely affected.

[0061]

Fig. 4 illustrates the characteristics of the surface acoustic wave filter according to this embodiment and the characteristics of a surface acoustic wave filter of a conventional example. Specifically, Fig. 4(a) illustrates an insertion loss, Fig. 4(b) illustrates the VSWR characteristics on the input side, and Fig. 4(c) illustrates the VSWR characteristics on the output side. In this case, this embodiment corresponds to the surface acoustic wave filter 350 having the specific design parameters described

above. In Fig. 4, the characteristics of the surface acoustic wave filter 350 are indicated by thin lines. As for the conventional example, the surface acoustic wave filter is basically the same as the surface acoustic wave filter 350 according to this embodiment except for the fact that the electrode fingers of the IDT 303 and the electrode fingers of the IDTs 302, 304 are arranged at the same pitch of 2.108 μm, and that the electrode fingers of the IDT 309 and the electrode fingers of the IDTs 308, 310 are arranged at the same pitch of 2.108 μm. In Fig. 4, the characteristics of the surface acoustic wave filter of the conventional example are indicated by thick lines.

[0062]

Comparing the VSWR characteristics between the two, it is apparent that the VSWR of the surface acoustic wave filter according to this embodiment is smaller (improved) in comparison to the VSWR of the surface acoustic wave filter of the conventional example with respect to most of the frequencies within the passband. In particular, the highest input-side VSWR at a low frequency end portion of the passband according to the surface acoustic wave filter of the conventional example is reduced significantly in the surface acoustic wave filter according to this embodiment.

[0063]

On the other hand, near the 935 MHz frequency range,

the VSWR of the surface acoustic wave filter of the conventional example is lower than the VSWR of the surface acoustic wave filter according to this embodiment. This is due to the fact that the parasitic capacitance between the cascade-connected wires and the grounding pattern near the 935 MHz frequency range acts in a direction for facilitating the impedance matching in the cascade-connected portion. In contrast, the effect of this parasitic capacitance is disturbed in this embodiment, which resulted in the deterioration of the impedance matching in the cascade-connected portion. Since the parasitic capacitance between the cascade-connected wires and the grounding pattern facilitates the impedance matching in the cascade-connected portion in a certain frequency range within the passband, the arrangement of the electrode fingers at smaller pitches does not necessarily mean that the VSWR characteristics are improved for all frequencies within the passband. However, the parasitic capacitance between the cascade-connected wires and the grounding pattern is generally excessive, and is thus a factor for deteriorating the impedance matching in the cascade-connected portion for most frequency ranges within the passband.

[0064]

Accordingly, by arranging the electrode fingers at narrower pitches as in the above embodiment, the VSWR can be

reduced for a large portion of the passband, meaning that the VSWR characteristics are improved as a whole.

[0065]

Since the effect of the parasitic capacitance between the cascade-connected wires and the grounding pattern tend to become too intense in proportion to the increase in the relative dielectric constant of the piezoelectric substrate or the increase in the frequency in the passband, the arrangement of the electrode fingers at narrower pitches according to this embodiment is effective for improving the VSWR characteristics.

[0066]

The present invention is not limited to the above-described embodiment, and modifications are permissible within the scope and spirit of the present invention.

[Brief Description of the Drawings]

[0067]

[Fig. 1] Fig. 1 is a schematic diagram of a surface acoustic wave filter (conventional example).

[Fig. 2] Fig. 2 is a schematic diagram of a surface acoustic wave filter (conventional example).

[Fig. 3] Fig. 3 is a schematic diagram of a surface acoustic wave filter (embodiment).

[Fig. 4] Fig. 4 includes graphs illustrating the characteristics of the surface acoustic wave filters

(embodiment, conventional example).

[Reference Numerals]

[0068]

350: surface acoustic wave filter (elastic-wave filter)

302, 303, 304: IDT

306: longitudinally-coupled-resonator-type surface-acoustic-wave filter element (longitudinally-coupled-resonator-type elastic-wave filter)

308, 309, 310: IDT

312: longitudinally-coupled-resonator-type surface-acoustic-wave filter element (longitudinally-coupled-resonator-type elastic-wave filter)

[Name of Document] ABSTRACT

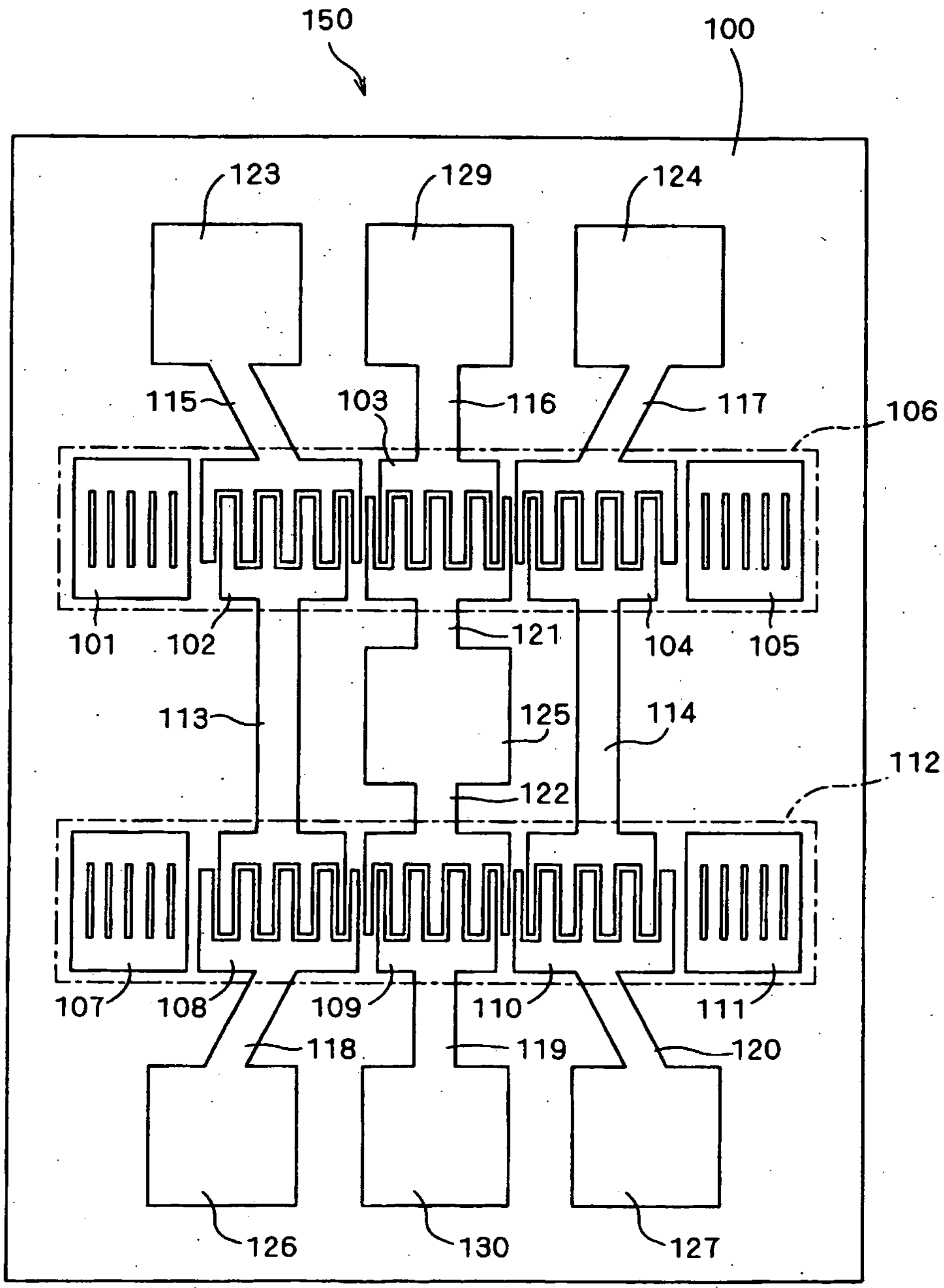
[Abstract]

[Object] In an elastic-wave filter having a plurality of cascade-connected longitudinally-coupled-resonator-type elastic-wave filter elements disposed on a piezoelectric substrate, an adverse effect of a parasitic capacitance in cascade-connected wires disposed between the longitudinally-coupled-resonator-type elastic-wave filter elements is reduced so as to improve impedance matching of a cascade-connected portion and to improve the VSWR characteristics of input-output terminals of the elastic-wave filter.

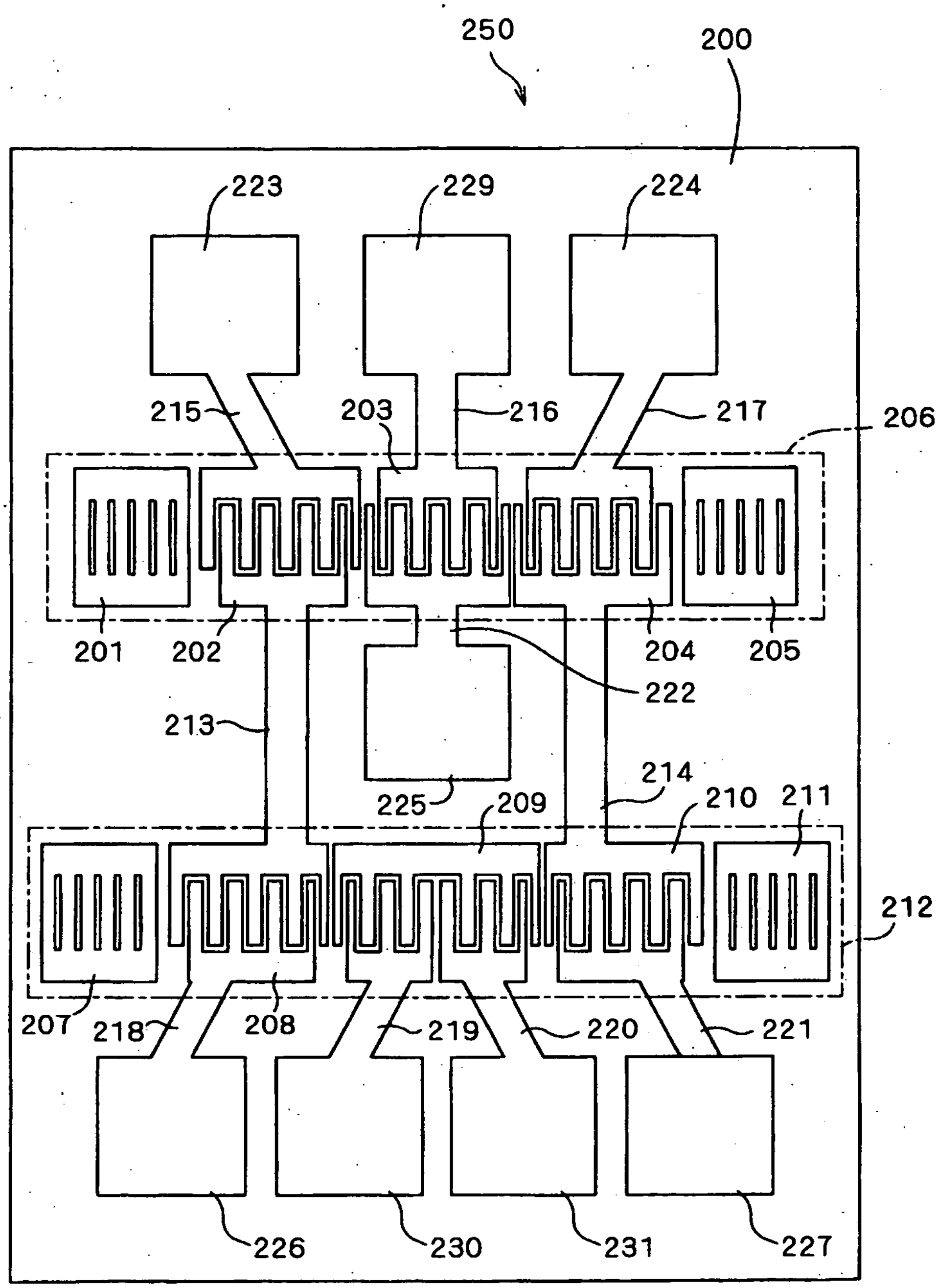
[Solving Means] An elastic-wave filter 350 includes two longitudinally-coupled-resonator-type elastic-wave filter elements 306, 312 that are cascade-connected with each other, each longitudinally-coupled-resonator-type elastic-wave filter element 306, 312 including three IDTs 302, 303, 304; 308, 309, 310 arranged on a piezoelectric substrate 300 in a transmitting direction of an elastic wave. In at least one of the longitudinally-coupled-resonator-type elastic-wave filter elements 306, 311, electrode fingers of the IDTs 302, 304; 308, 310 that are cascade-connected are arranged at a pitch that is smaller than a pitch of electrode fingers of the remaining IDT 303; 309.

[Selected Figure] Fig. 3

【書類名】図面　[Name of Document] DRAWINGS
【図１】 [FIG. 1]



【図２】 [FIG. 2]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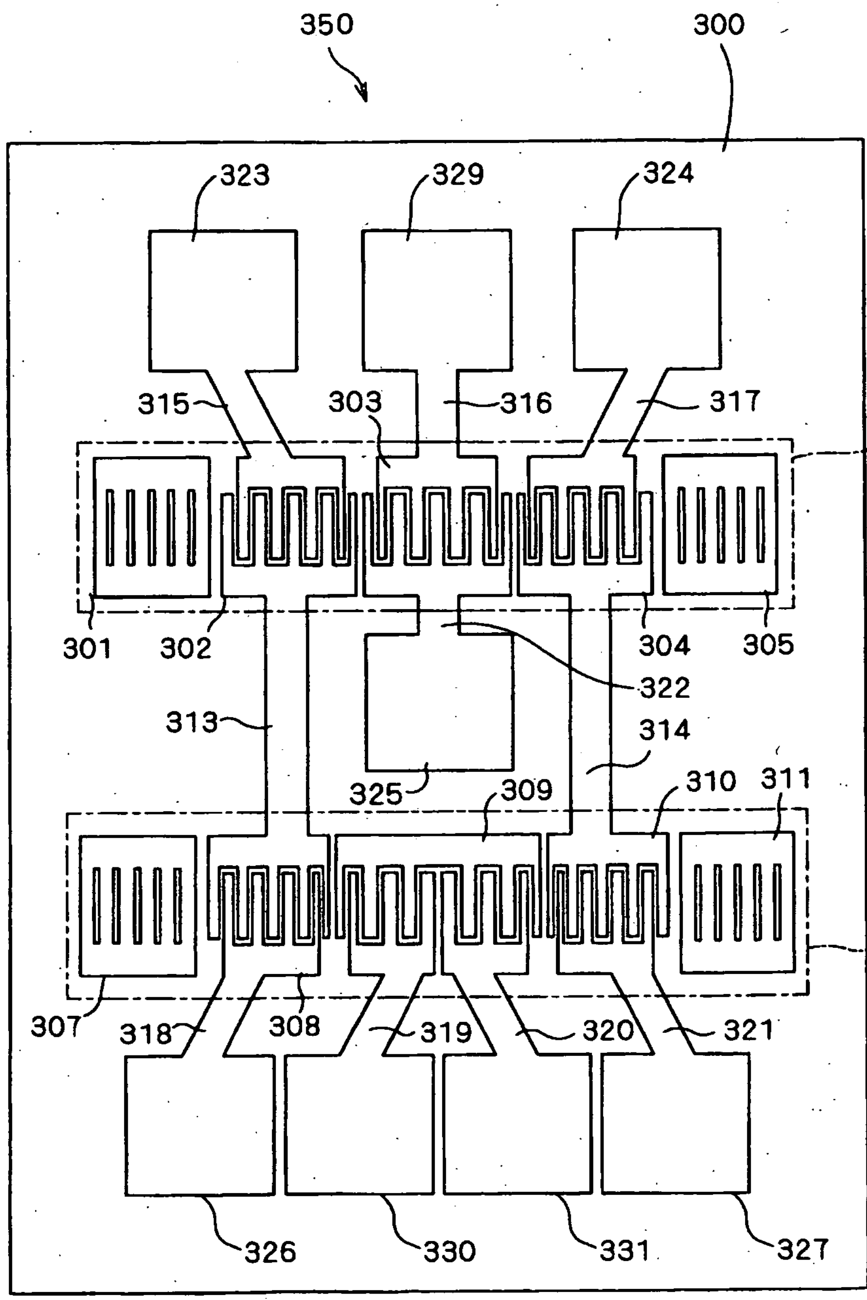
【図３】　[FIG. 3]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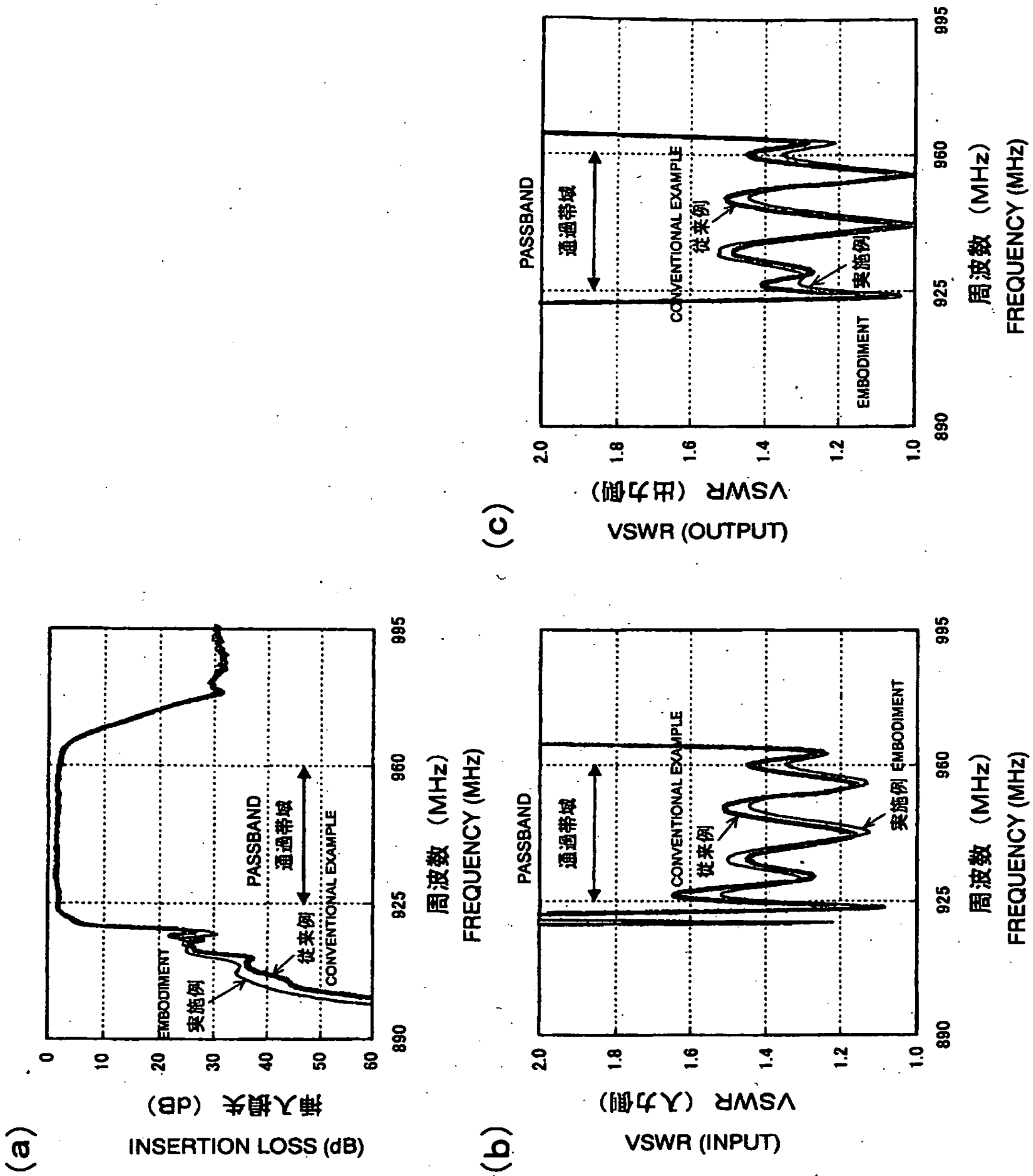
【図４】　[FIG. 4]



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INSERTION LOSS (dB)
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30
40
50
60
890
925
960
995
周波数 (MHz)
FREQUENCY (MHz)
PASSBAND
通過帯域
従来例
CONVENTIONAL EXAMPLE
EMBODIMENT
実施例
(b)
VSWR (入力側)
VSWR (INPUT)
2.0
1.8
1.6
1.4
1.2
1.0
PASSBAND
通過帯域
CONVENTIONAL EXAMPLE
従来例
実施例
EMBODIMENT
(c)
VSWR (出力側)
VSWR (OUTPUT)